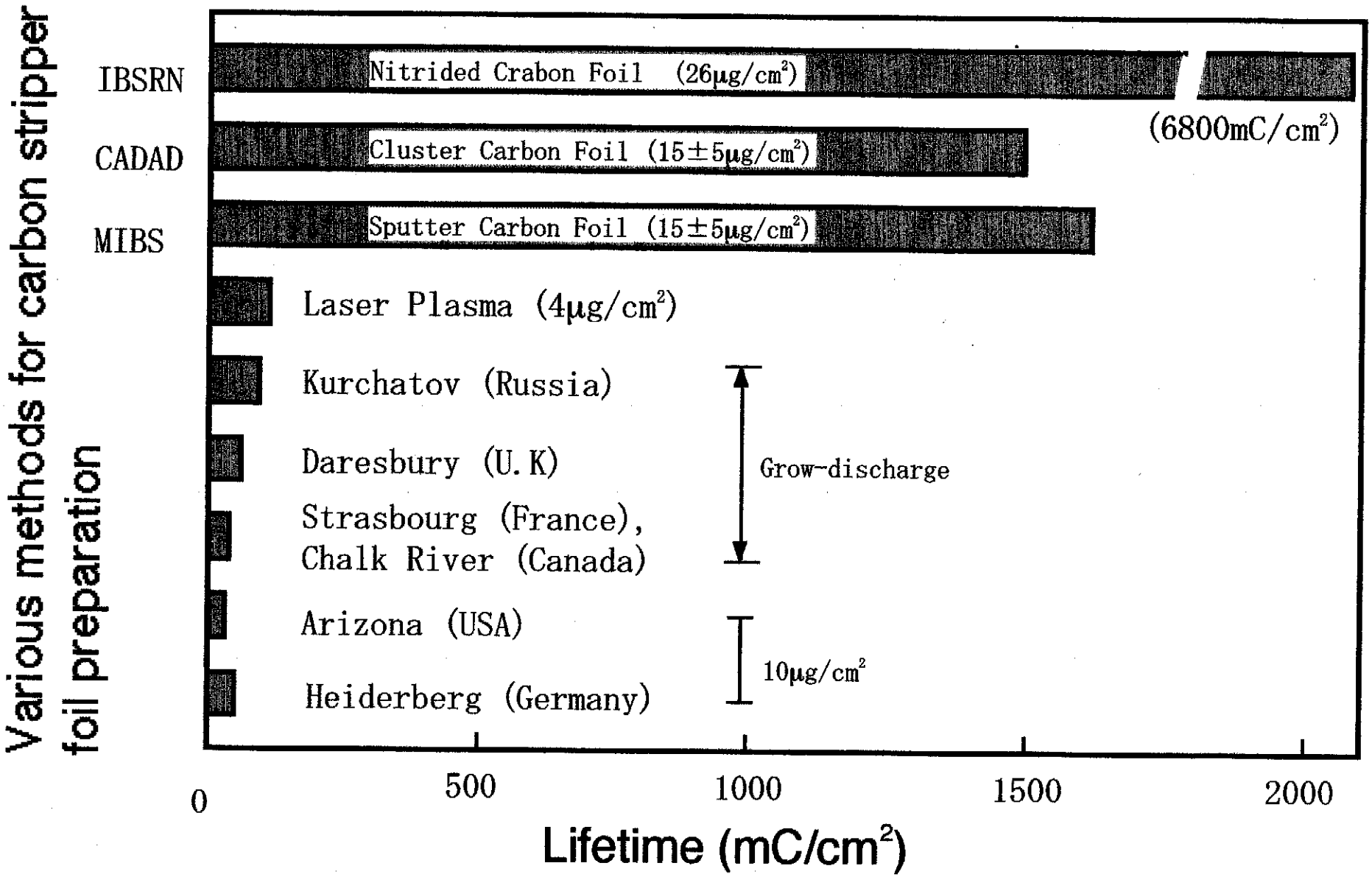
Present Status of Development of Long-Lived Cluster and Hybrid Carbon Stripper Foils at KEK

I. Sugai[1*], Y. Takeda[1], M. Oyaizu[1], H. Kawakami[1], Y. Irie[1],
Y, Arakida[1], I. Yamane[1], M. Kinsho[2], T. Hattori[3], K. Kawasaki[3],

1 High Energy Accelerator Research Organization,
2 Japan Atomic Energy Research Institute
3 Tokyo Institute of Technology,

Talks:

- Introduction
- Preparation of carbon stripper foils by a CADAD method
- **Development of a controlling method of the carbon build-up on thin carbon stripper foils during beam irradiation**
- Lifetime measurements of carbon stripper foils with a low energy 3.2MeV, Ne^{+} beam
- Instruments for development of new type of thick carbon stripper foils for 3GeV proton strage ring accelerator
- Summary



3.2MeV, $^{20}Ne^{+}$ ion beam of 2-3μA with a 3.5mmϕ beam spot

In "Controlled DC Arc-Discharge",

Two kinds of Different Sized Carbon Clusters are emitted as;

Larger one ; $\sim$ 0. 3 μm   from *Cathode*

Smaller one ; $\sim$ 0.003 μm   from *Anode*

Life Times of Foils are very *Sensitive to* the Ratio ;

$$R = \frac{W_c}{W_c + W_a} \times 100\ (\%)$$

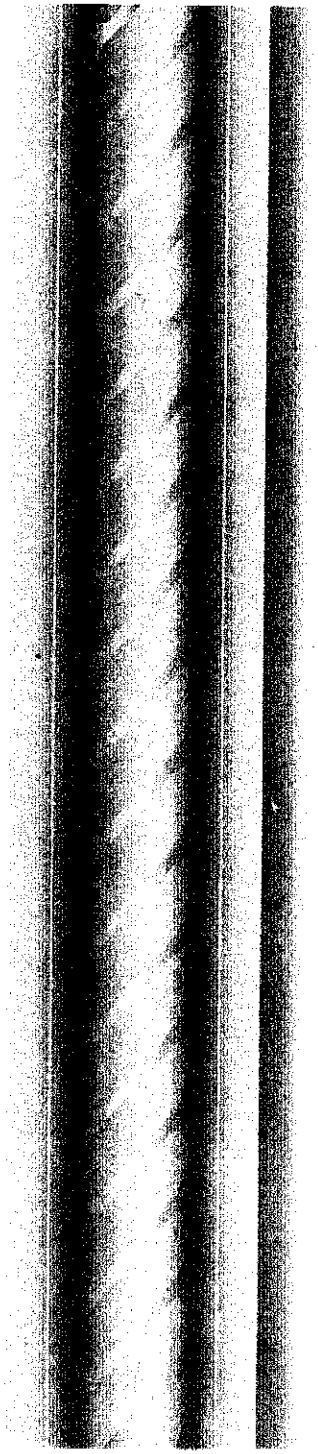
where W_c and W_a are the Discharged Amounts of Carbon [illegible]
(Carbon Source Materials)
from Cathode and Anode, [illegible] and so [illegible]
the DC arc discharge.

We developed

[illegible] System of DC and AC Arc-Discharge [illegible]

which is very easy to control the R in simple way.

Controlled DC Arc Discharge



2. Foil Development by CADAD

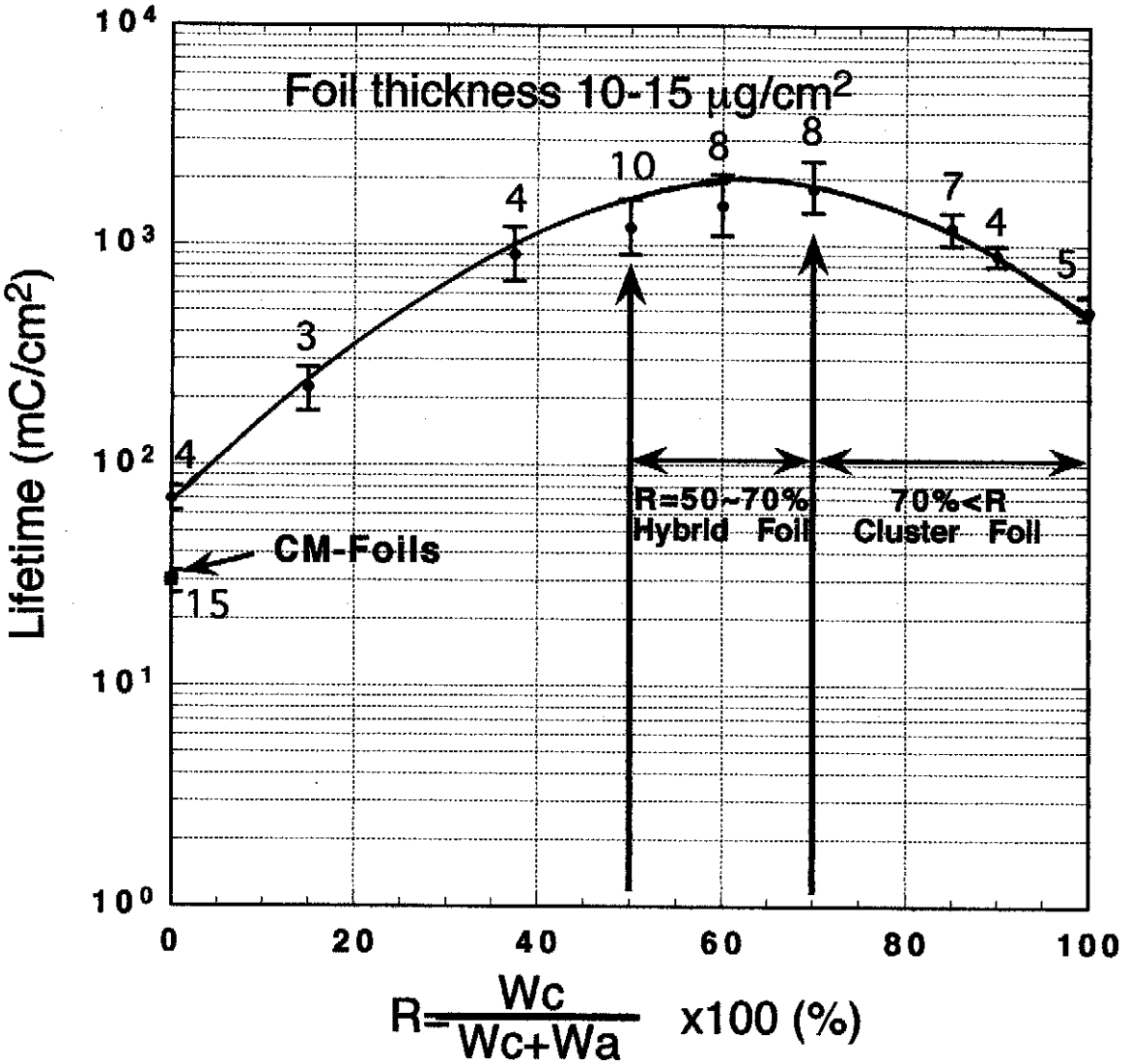
Foils made by DC-arc Discharge:
Very strong for heavy ion with High Intensity.

Foils made by AC arc-Discharge:
Very strong for mechanical strength

By combined (A) and (B)

⇩

We developed a Controlled AC・DC Arc-Discharge Method.



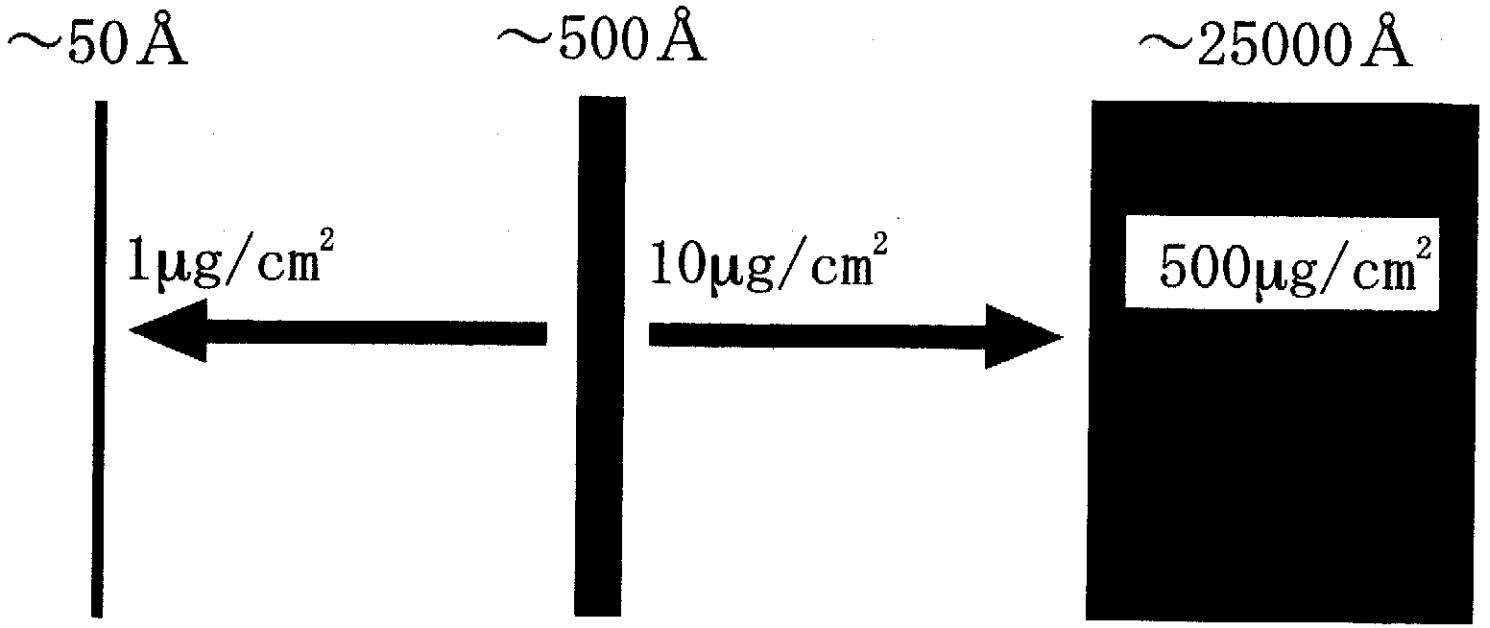
Relationship between the ratio R and the lifetime (Lifetime measurements were performed with a 3.2MeV, Ne^+ at 2.5±0.5μA of 3.5mmϕ beam spot)

Total and partial pressures of the residual gases in the chamber (unit : Torr)

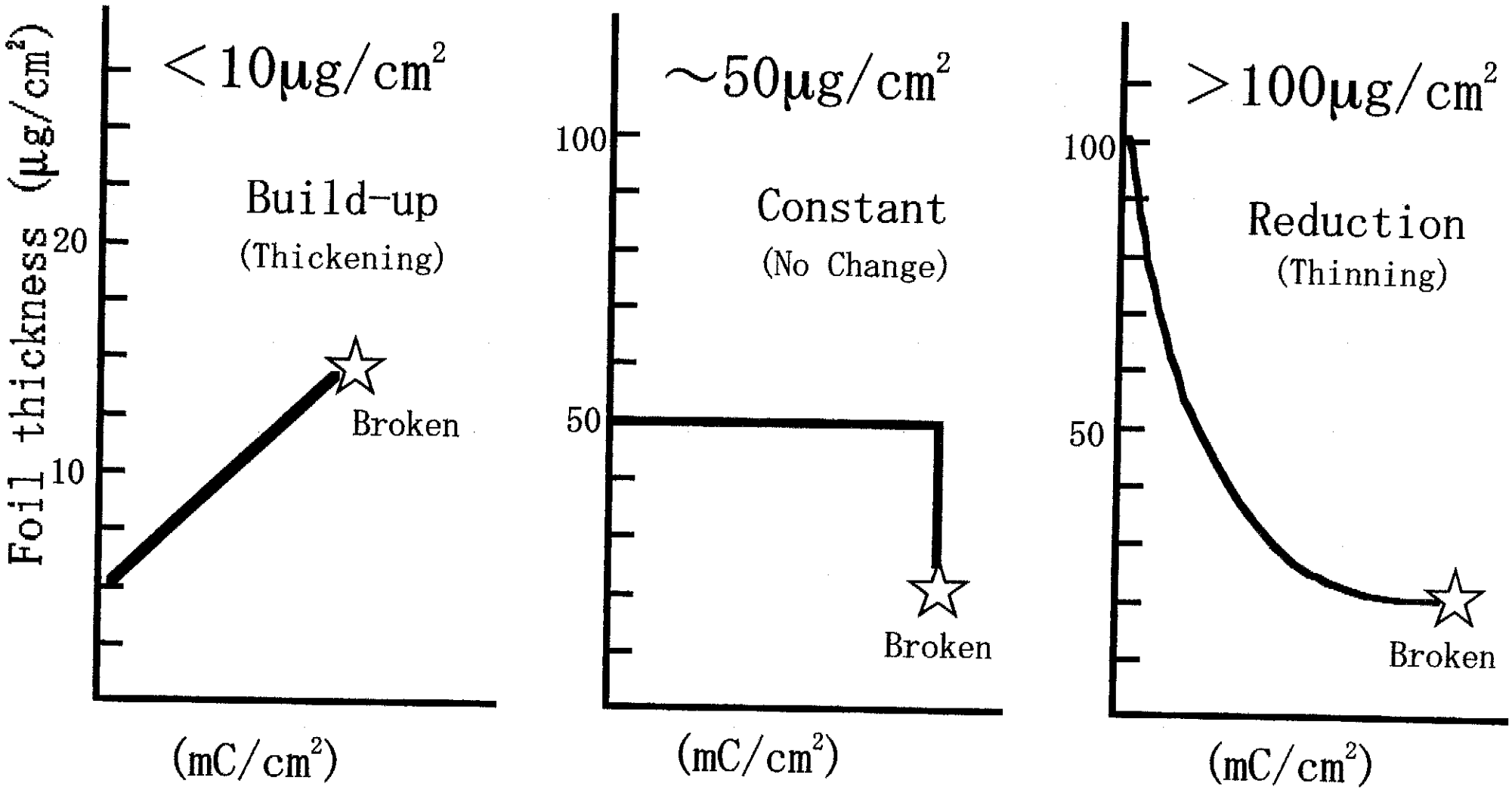
Tp	H_2	CH_4	H_2O	N_2	CO	O_2	CO_2	HC
2.0×10^{-5}	5.8×10^{-7}	6.3×10^{-7}	7.6×10^{-6}	9.2×10^{-7}	7.8×10^{-7}	3.3×10^{-7}	3.4×10^{-7}	9.6×10^{-6}

Total pressure is very poor, 2.0×10^{-5} Torr

— Very thin to Very thick —



Challenge to the utmost limit thickness
by using CADAD method



Thickness changes under $^{20}Ne^{+}$ ion irradiation of 3.2MeV and 1~3 μA of 3.5φ beam spot
Three different evidences: Thickening. Non change and Thinning

What is the essential point for heavy ion stripper foil?

It is "thin and long lifetime"

Thin foil → High beam transmission

→ Contrary to "Long lifetime"

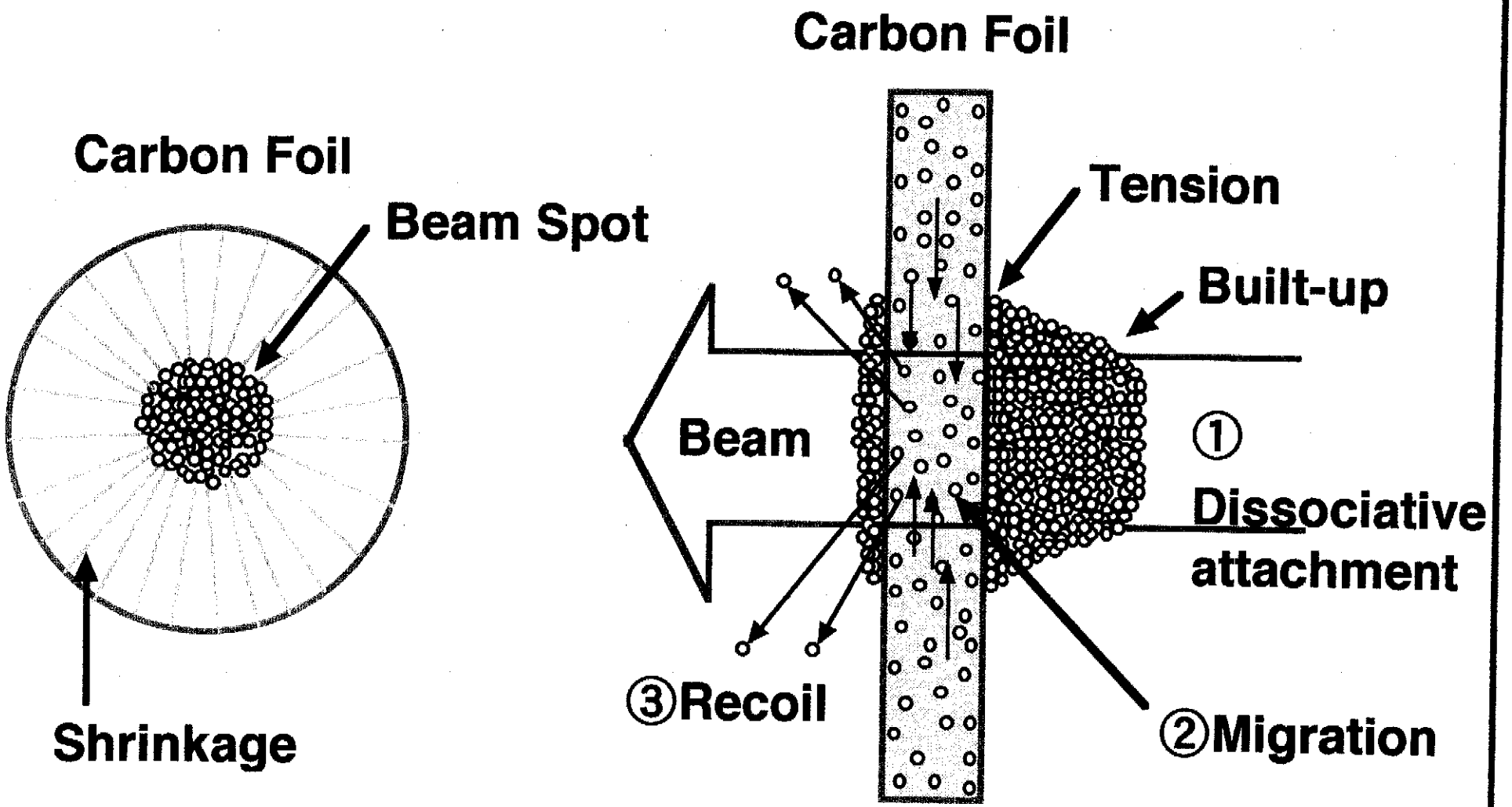
Build-up phenomena plays seriously negative role to

① Beam transmission

② Lifetime

Hence, it is

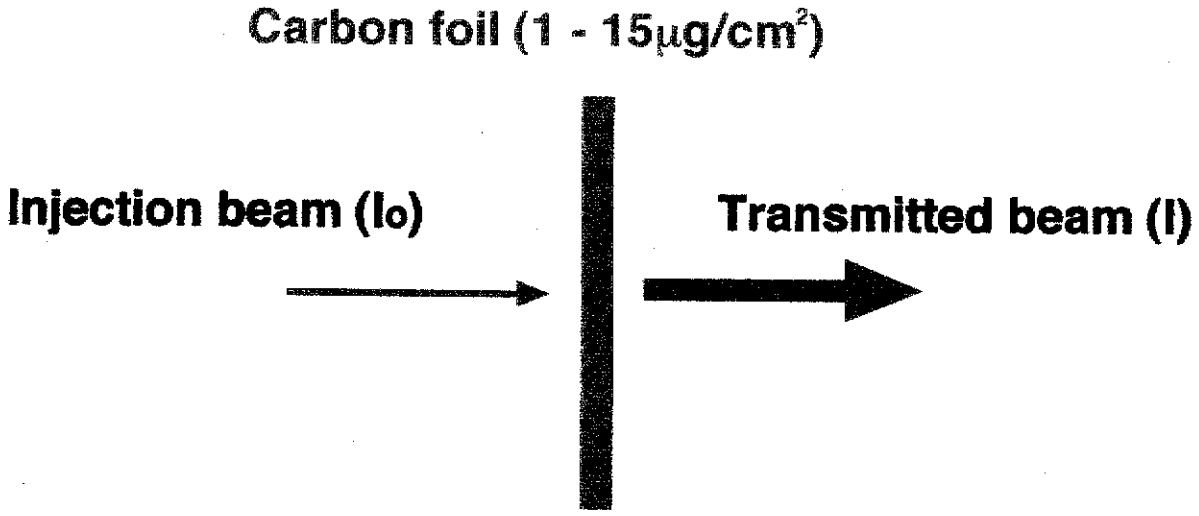
"very important to control the build-up"

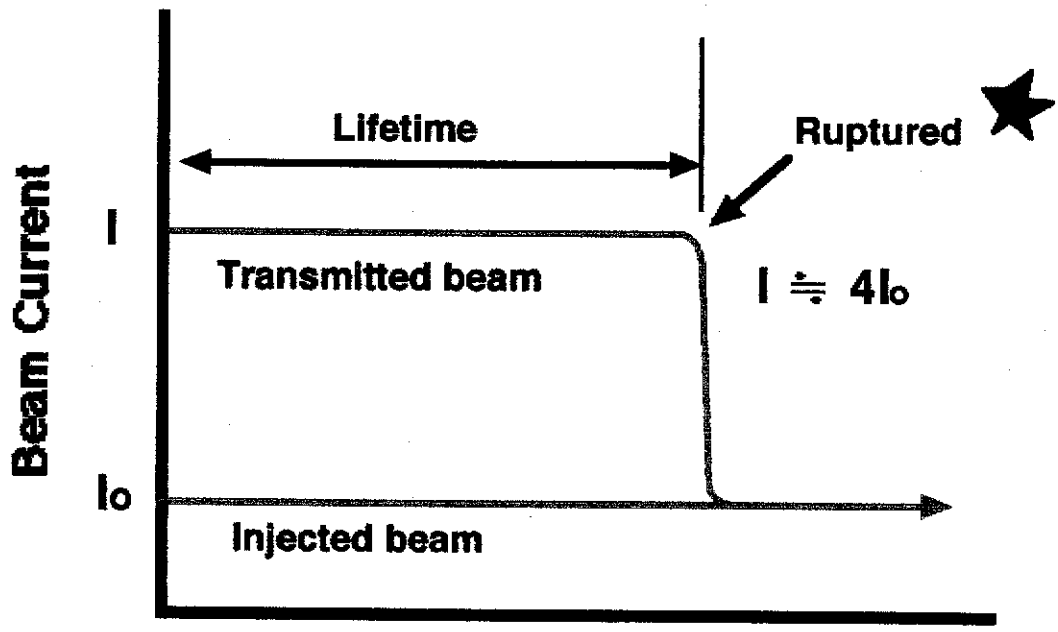


Sources of highly transmission

Lifetime Measurment with a 3.2 MeV Ne^+ Ion Beam

Definition of Lifetime:
Integrated beam current (mC) per unit area (cm^2)
$[I_o \cdot T]$

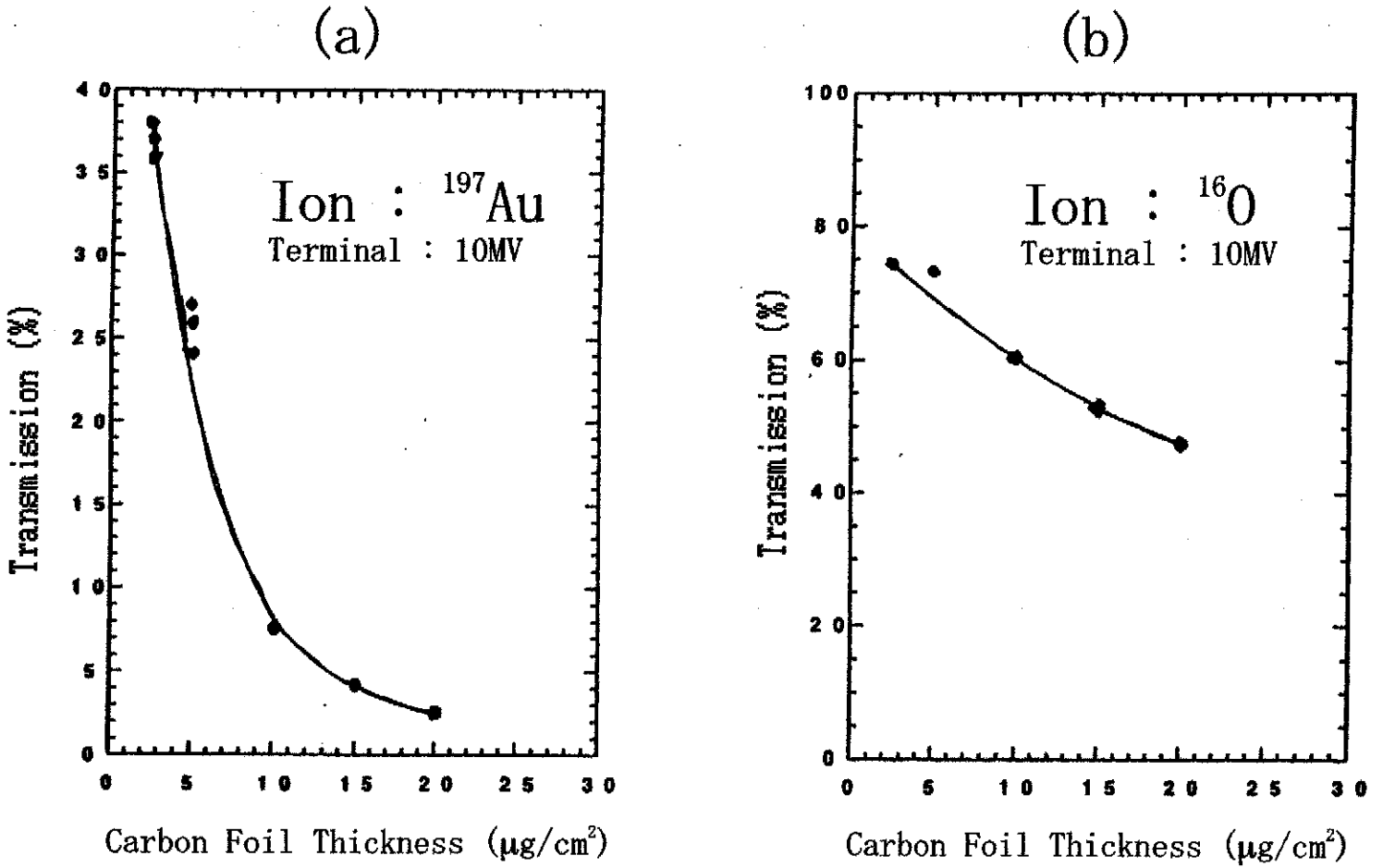




We have found that carbon build-up is very sensitive to the foil temperature

We measured:

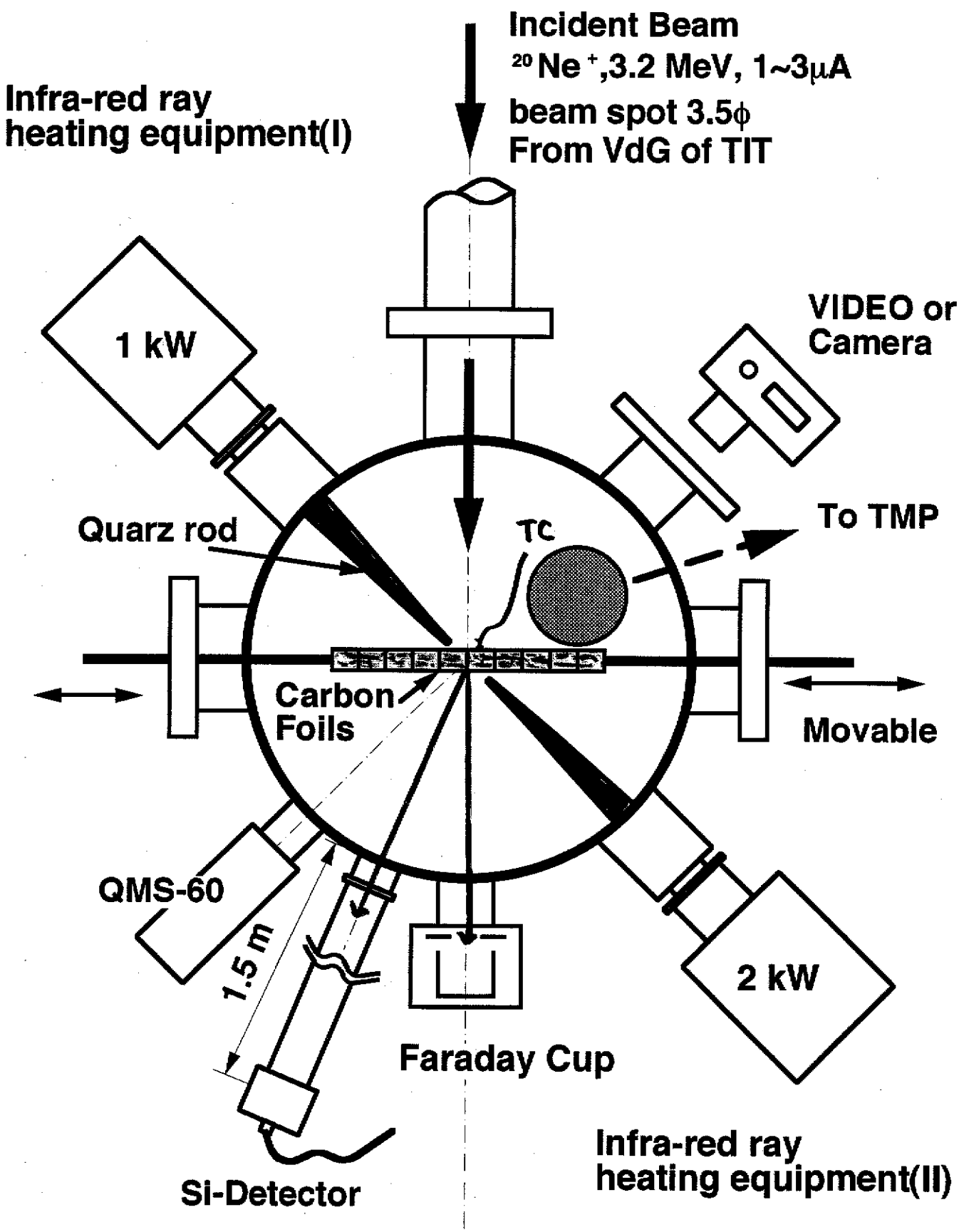
- Carbon build-up vs Temperature
- Lifetime vs Temperature
- Lifetime vs Carbon build-up



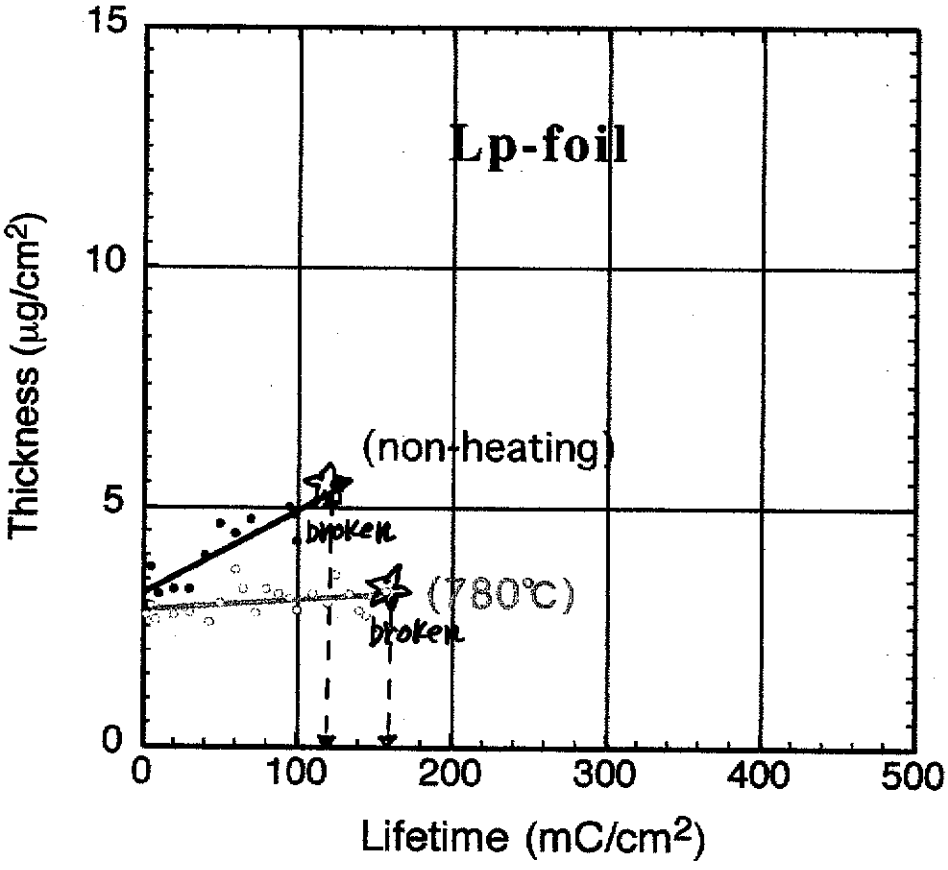
Transmission reduction (95%)

Transmission reduction (36%)

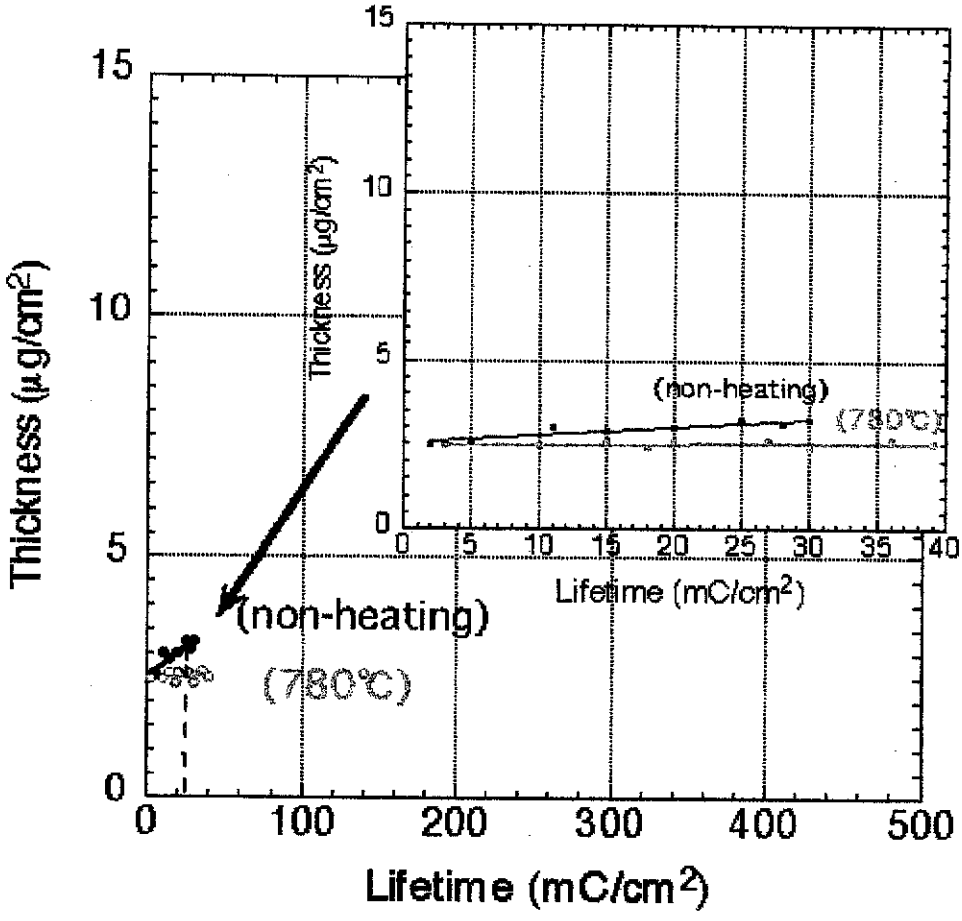
Measured trasmission of (a) Au ions and (b) O ions in Tandem accelerator (University of Tsukuba) at the terminal voltage 10 MeV as function of carbon stripper foil thickness

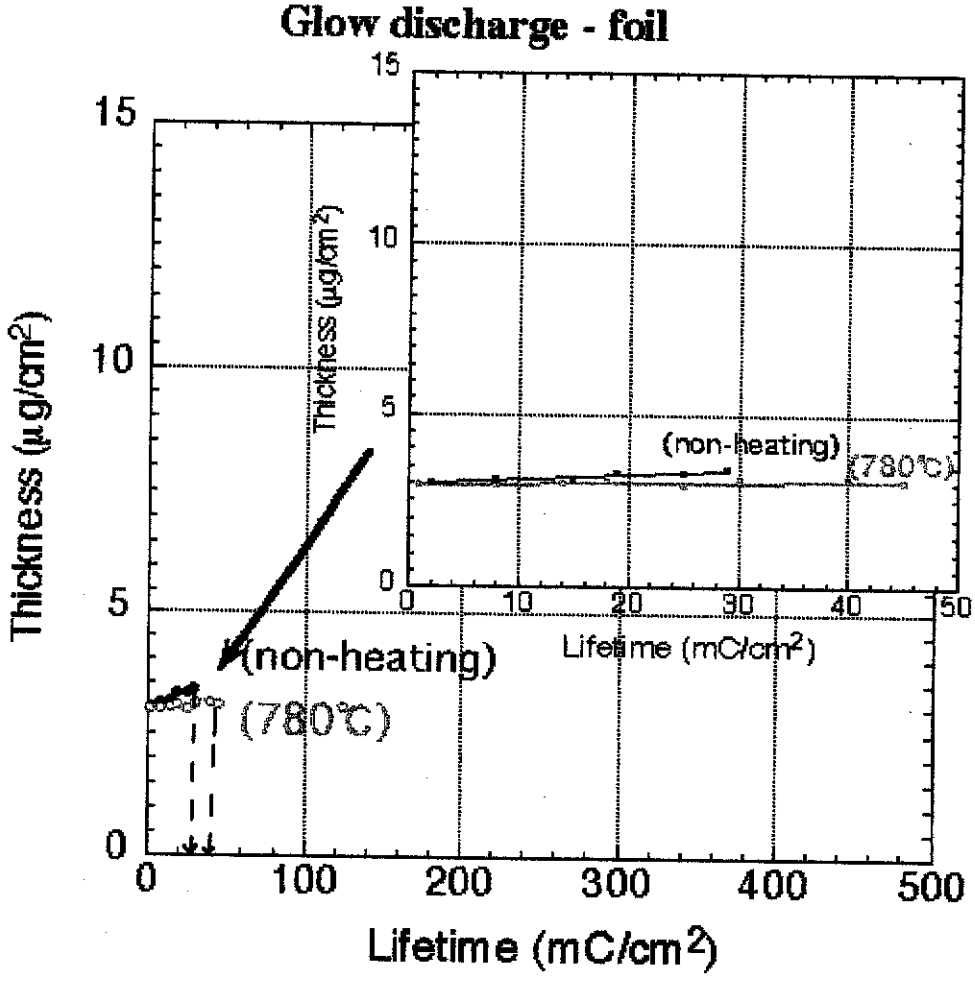


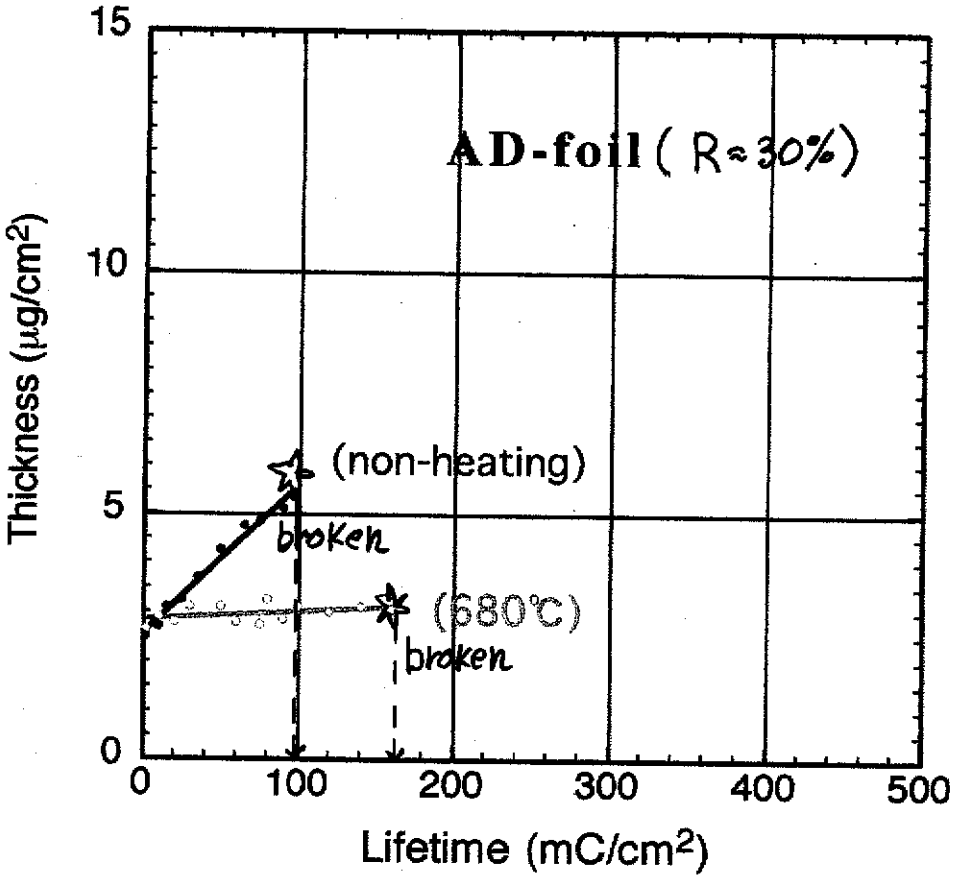
Experimental Setup for the lifetime measurements

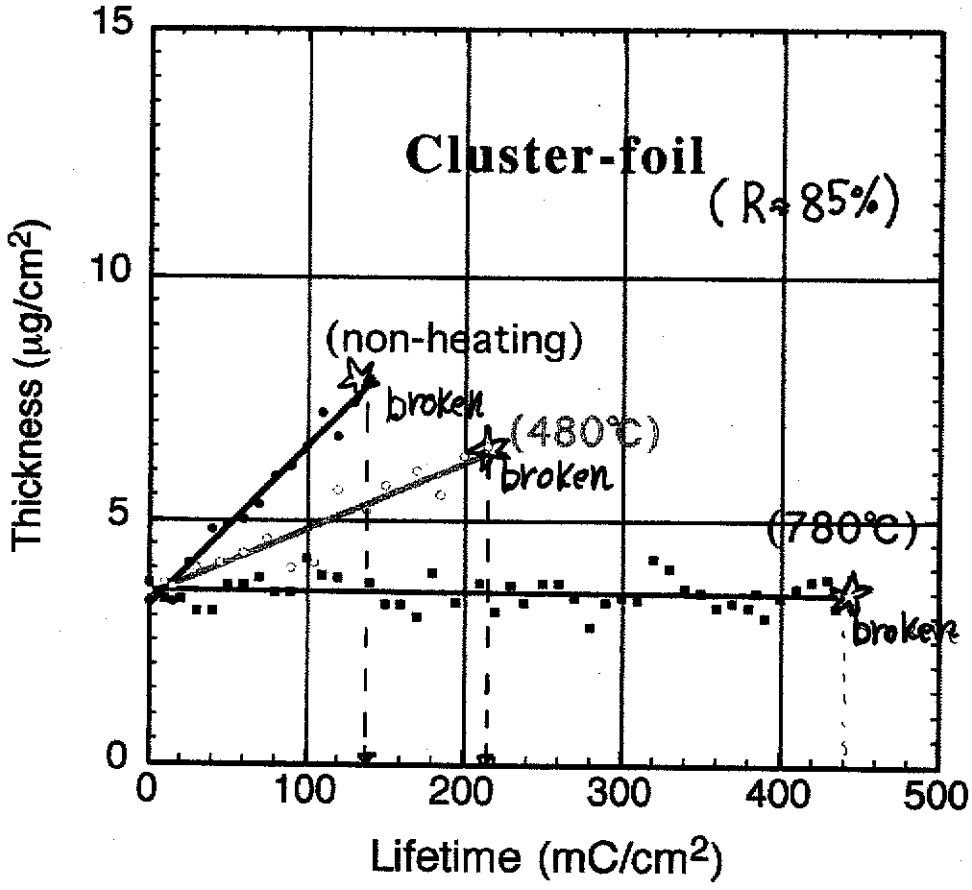

Lp-foil
(non-heating)
broken
(780℃)
broken
Thickness (μg/cm²)
Lifetime (mC/cm²)
0
5
10
15
0
100
200
300
400
500

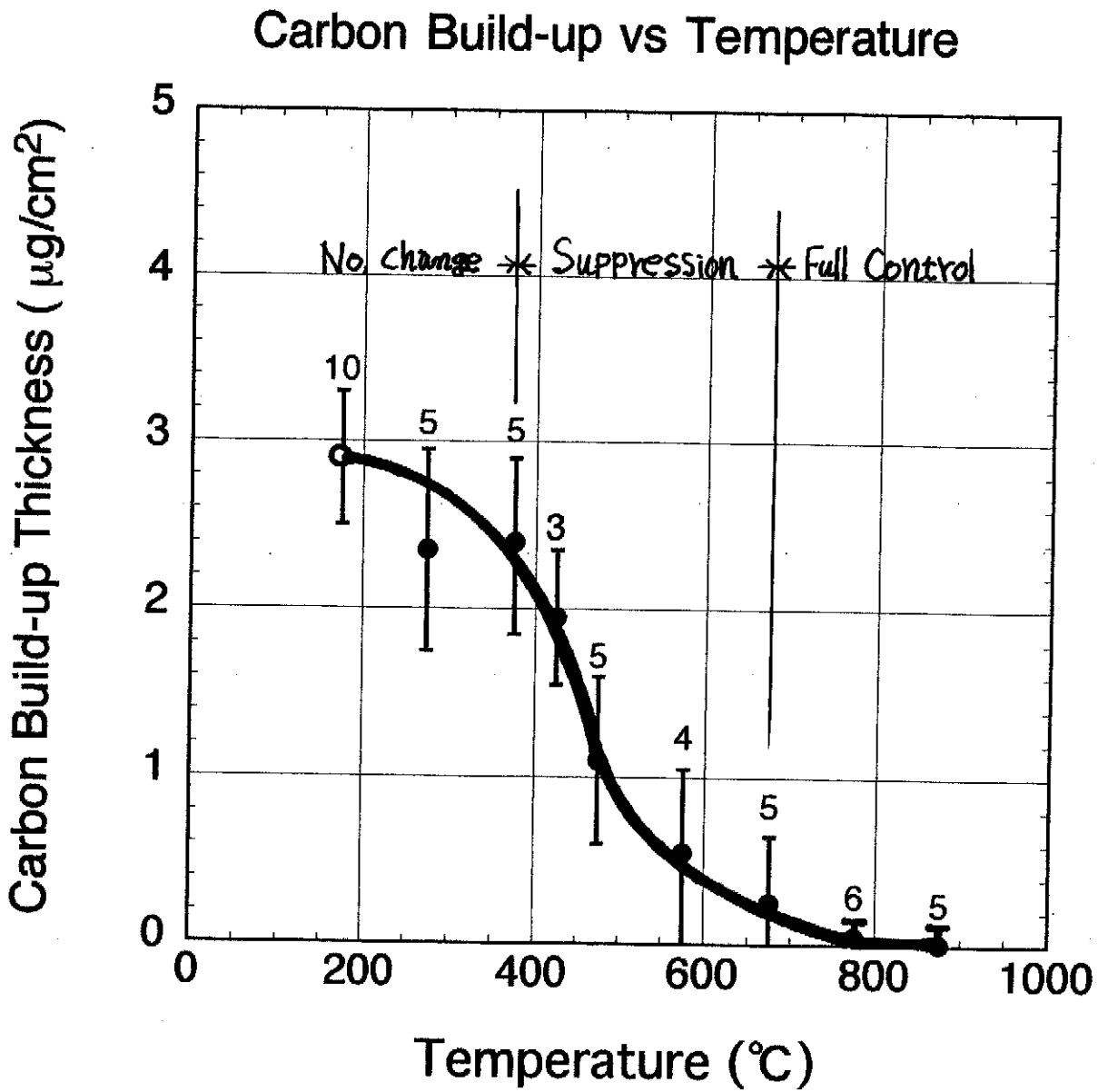
Arizona-foil

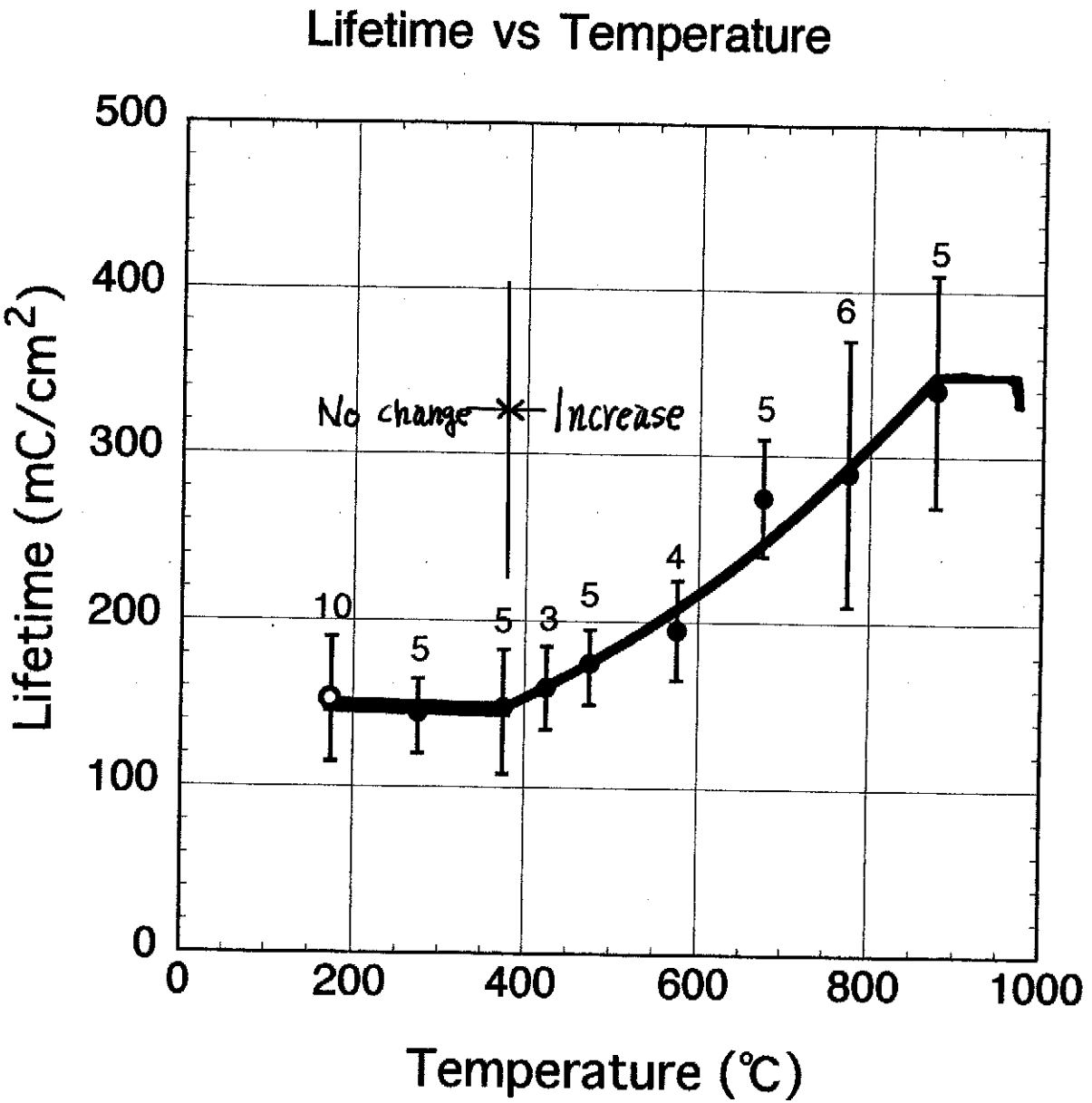


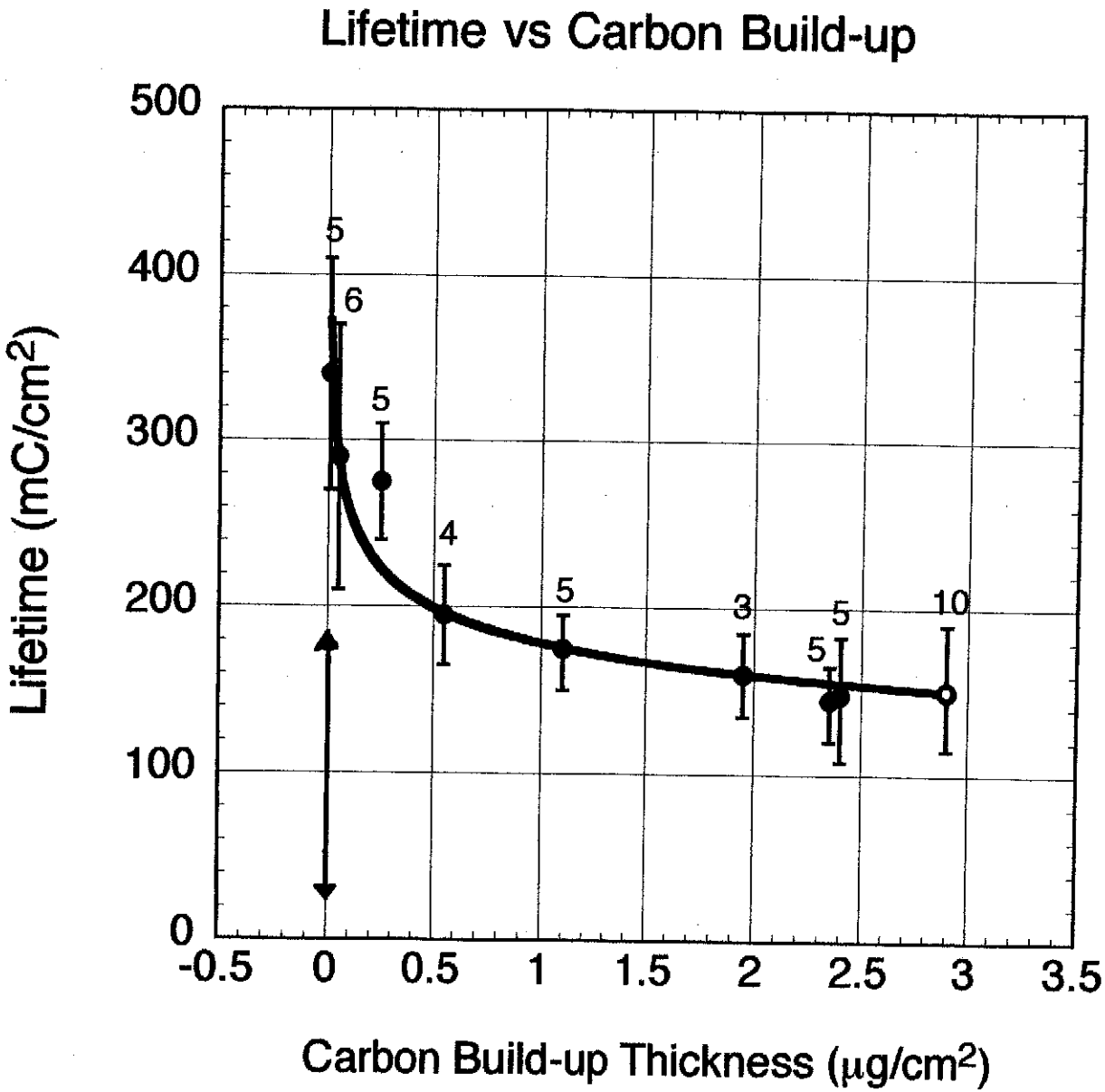

Glow discharge - foil
Thickness (μg/cm²)
Lifetime (mC/cm²)
(non-heating)
(780℃)
0
5
10
15
0
100
200
300
400
500
0
5
10
15
0
10
20
30
40
50


AD-foil (R≈30%)
(non-heating)
broken
(680℃)
broken
Thickness (μg/cm²)
Lifetime (mC/cm²)
0
5
10
15
0
100
200
300
400
500

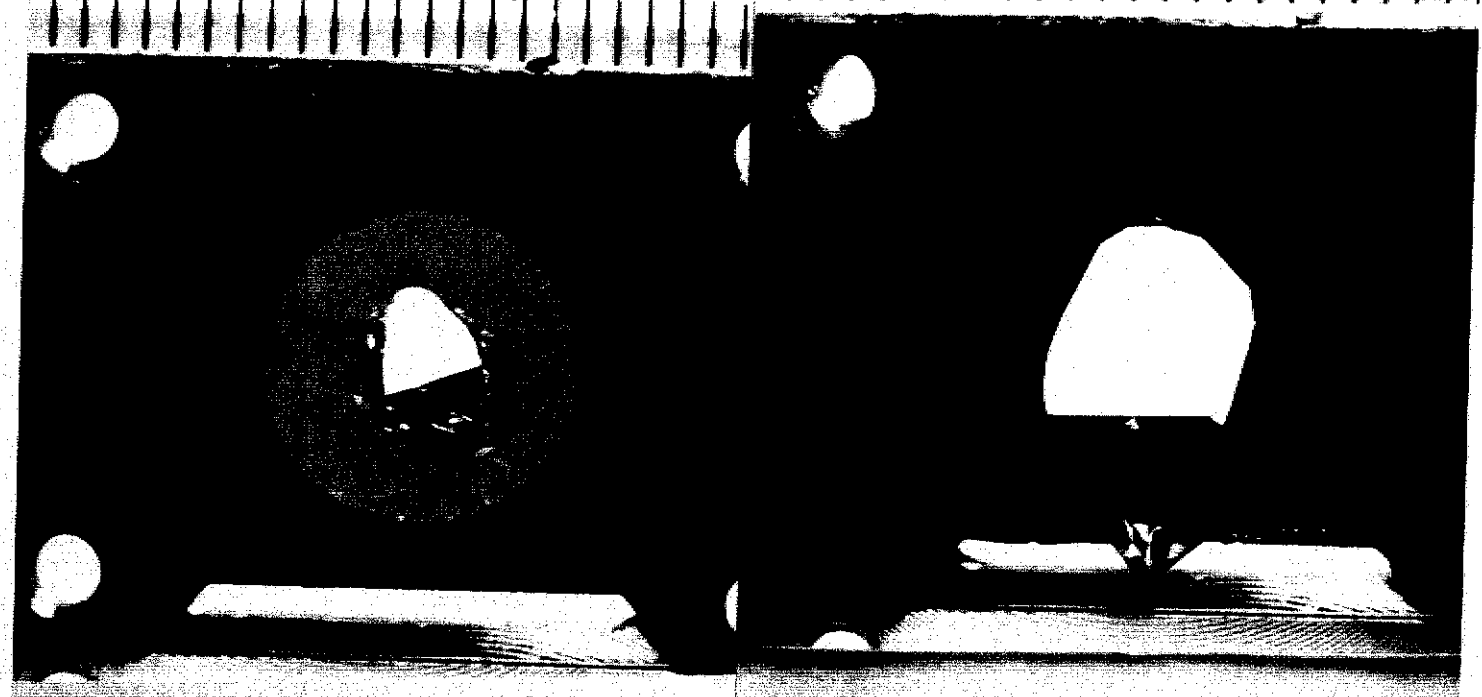

Cluster-foil
(R~85%)
(non-heating)
broken
(480℃)
broken
(780℃)
broken
Thickness (μg/cm²)
Lifetime (mC/cm²)
0
5
10
15
0
100
200
300
400
500


Carbon Build-up vs Temperature
Carbon Build-up Thickness (μg/cm²)
Temperature (℃)
No change
Suppression
Full Control
10
5
5
3
5
4
5
6
5
0
1
2
3
4
5
0
200
400
600
800
1000


Lifetime vs Temperature
Lifetime (mC/cm^2)
Temperature (℃)
500
400
300
200
100
0
0
200
400
600
800
1000
No change
Increase
10
5
5
3
5
4
5
6
5


Lifetime vs Carbon Build-up
Lifetime (mC/cm2)
500
400
300
200
100
0
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
Carbon Build-up Thickness (μg/cm2)
5
6
5
4
5
3
5
5
10

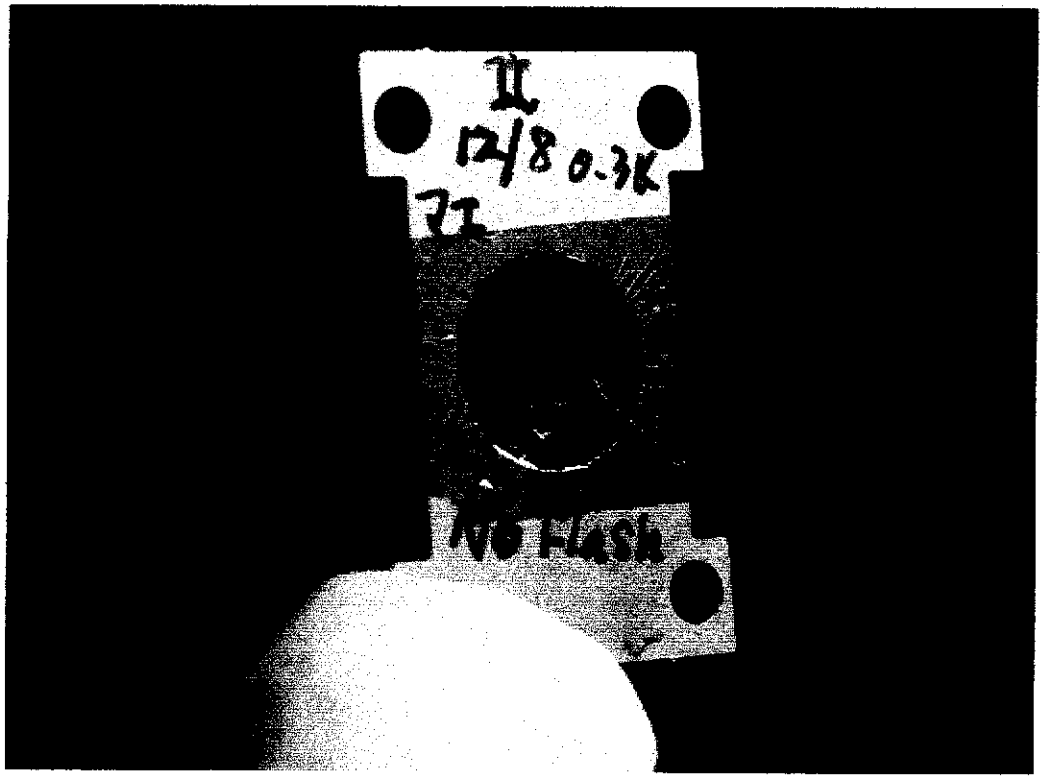
各種成膜の破損のパターン

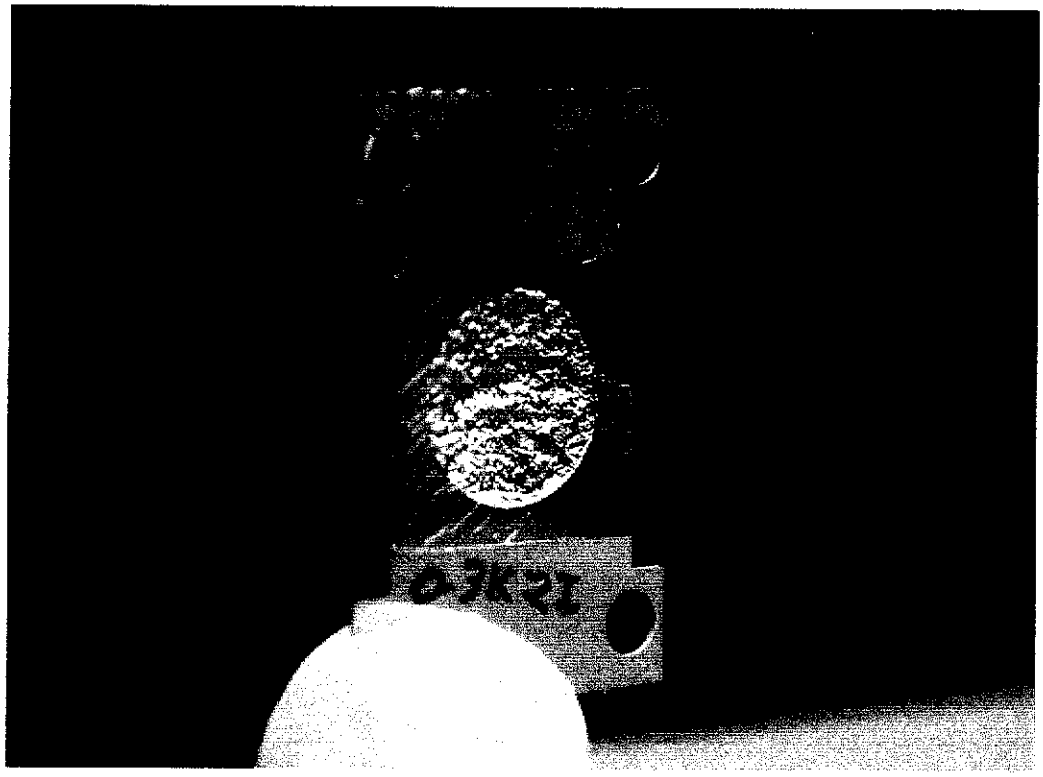


① Yissum ② ARIZONA

③ Electron beam

④ Controlled DC (Arc-Discharge (CDA)


II
1/8 0.3K
NO FLASH


0.3KRI